

Another important sustainability perspective is that targeted light regulation may reduce dependence on chemical inputs and labor-intensive corrective practices. Preharvest red LED light has been shown to increase fruit yield and quality while improving tolerance to *Botrytis cinerea*, supporting the possibility that optimized light environments could contribute to future reductions in agrochemical use. At the industry level, broader strawberry production reviews also emphasize that future commercial systems will rely on new technologies, protected-environment systems, and management innovations to maintain high-quality production under mounting climatic and biological pressures.

The accumulated evidence indicates that light management is already a powerful tool for improving strawberry yield, sugar accumulation, pigmentation, and overall fruit quality, but the next advance will depend on moving from empirical recipes to mechanism-guided control. Existing reviews agree that artificial lighting can optimize fruit production and sensory quality, yet also stress that information remains limited on how specific light properties shape productivity and secondary metabolite accumulation in strawberry. Recent biotechnology-focused synthesis reaches a similar conclusion by emphasizing that strawberry quality formation is shaped by interactions among developmental stage, stress, and external regulation, and that modern tools such as omics, LED regulation, and gene-based approaches now offer a stronger basis for targeted intervention.

Several research gaps stand out clearly. One is the need for more work on underexplored spectral regions and treatment windows, especially preharvest UV-A, preharvest UV-C, and cultivar-by-temperature interactions under visible spectra. Another is the need for longer-term validation, because recent controlled-environment engineering work explicitly calls for studies on scalability across environments and long-term effects on plant health, yield stability, nutritional quality, and flavor characteristics.

Postharvest performance should also become a more central research target, because fruit quality benefits produced before harvest are only valuable if they persist through storage and transport. Current synthesis highlights rapid postharvest deterioration as a major constraint in strawberry and calls for more development of green prevention and control measures to support disease-free, high-quality fruit. This complements earlier calls to monitor flavonoid degradation after harvest and determine how long light-induced benefits are retained during storage and distribution.

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